Evaluation of the Moderate Resolution Imaging Spectrometer special 3.95-μm fire channel and implications on fire channel selections for future satellite instruments

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Abstract. The 3.75-μm and 11-μm channels on the polar orbiting NOAA Advanced Very High Resolution Radiometer (AVHRR) sensors have saturation temperatures of approximately 325 K. They allowed limited successes in estimating the sub-pixel fire temperature and fractional area coverage. The saturation problem associated with the 3.75-μm AVHRR channel greatly limited the ability for such estimates. In order to overcome this problem, the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on the NASA Terra and Aqua spacecrafts have both been equipped with a special fire channel centered at 3.95 μm with a specified saturation temperature of 500 K and a spatial resolution of 1 km. We have analyzed more than 40 sets of Terra and Aqua MODIS fire data acquired over different geographical regions, and found that very few fire pixels have the 3.95-μm fire channel brightness temperatures greater than 450 K. We suggest that the saturation temperature of fire channels near 4 μm for future satellite instruments with pixel sizes of about 1 km should be specified at about 450 K or even slightly lower in order to make the channels more useful for quantitative remote sensing of fires. A dual gain approach should also be considered for future satellite fire channels.

Keywords: MODIS, satellite instrument, fire channel.

1 INTRODUCTION

Biomass burning is a major source of trace gases and aerosol particles, with significant ramifications for atmospheric chemistry, cloud optical and micro-physical properties, and radiation budgets [1]. Remote sensing of fires and hot surfaces on regional and global scales can be made from satellite platforms. For examples, the polar orbiting NOAA Advanced Very High Resolution Radiometer (AVHRR) sensors and the visible atmospheric sounder (VAS) sensors on the Geostationary Orbiting Environmental Satellite (GOES) platforms have been used for remote sensing of fires [2], [3]. Dozier [4] first introduced a theoretical technique to study sub-pixel temperature fields using the 3.75- and 11-μm AVHRR channels. He approximated the temperature field of each pixel by two areas of uniform temperature: the background area and a target area, which occupies a fraction of the pixel. Dozier demonstrated that a sub-resolution high temperature target is detectable because it has a greater sensitivity in the 3.75-μm channel than in the 11-μm channel. Matson and Dozier [5] applied this fire detecting approach to AVHRR data on fixed targets with known locations – a high temperature industrial source in Detroit and waste gas flares in the Persian Gulf. Matson

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et al. [2] used AVHRR images over the United States and Brazil for fire detections based on enhanced brightness temperatures (BTs) in the 3.75-μm channel. Numerous other researchers [6], [7], [8], [9], [10], [11], [12]. [13] have reported fire detections using BT differences between channels near 4 μm and 11 μm as one of the detecting criteria.

The 3.75-μm and 11-μm AVHRR channels were originally designed mainly for remote sensing of clouds and sea surface temperatures (SST). The two channels have saturation temperatures of approximately 325 K. Although they allowed limited successes in estimating the sub-pixel fire temperature and fractional area coverage, the saturation problem associated with the 3.75-μm AVHRR channel over hot surfaces greatly limited the ability for such estimates [5]. In order to overcome this problem, the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments [14], [15] on the NASA Terra and Aqua spacecrafts have both been equipped with a special fire channel centered near 3.95 μm with a specified saturation temperature of 500 K. The channel has a spatial resolution of 1 km at nadir. It was hoped that the increased saturation level would permit better estimates of sub-pixel fire temperature and fractional area coverage from MODIS data. Although more than seven years of Terra MODIS data are now publicly available, we are unaware of any reported studies in the literature on simultaneous retrievals of sub-pixel fire temperatures and area fractions from MODIS data. The noise and calibration uncertainty of the special 3.95-μm fire channel make it difficult to perform the studies.

We have analyzed Terra and Aqua MODIS fire data sets acquired over different geographical regions, and systematically studied 3.95-μm BT distributions for fire pixels. In this paper, we report our observations from the MODIS data sets. We also present recommendations on selection of saturation temperatures of fire channels near 4 μm for future satellite instruments.

Table 1. Main characteristics of three MODIS channels and two AVHRR channels commonly used for fire detections.

Channel	Center Wavelength (μm)	Maximum T (K)
MODIS Ch. 21	3.959	500
MODIS Ch. 22	3.959	328
MODIS Ch. 31	11.03	400 (Terra MODIS) 340 (Aqua MODIS)
AVHRR Ch. 3	~3.75	~325
AVHRR Ch. 4	~10.8	~325

5 SUMMARY

Through analysis of MODIS fire data sets acquired over different geographical locations, we have found that very few fire pixels have brightness temperatures greater than 450 K for the special fire channel near 4 μm. We feel that the saturation temperature of the fire channel, although decreased from the initial 700 K to 500 K, should have been decreased further. It is recommended that the saturation temperature of fire channels near 4 μm for future satellite instruments with pixel sizes of about 1 km on the ground should be specified at about 450 K or even lower to 400 K in order to make the channels more useful for quantitative remote sensing of fires.